Light and the Circadian System

CEC Partner Visit
Lighting Research Center

April 8, 2003

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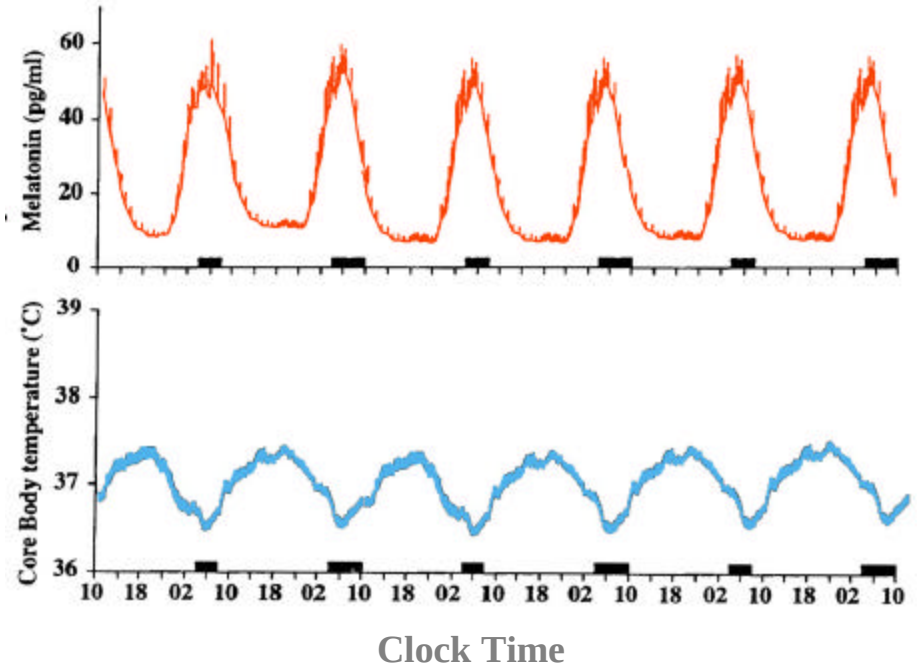
Circadian photobiology: Current knowledge

- The outlines of the physiology of the human circadian system are established
- The circadian system operates through an internal clock whose period is entrained by an external light / dark signal



Why is regulation of the circadian system important?

- Synchronize physiological functions with solar day; regular sleep/wake cycle:
  - Regulates bodily functions
  - Alertness / productivity during the day
  - Attendance / societal participation
  - Alzheimer's: Avoid institutionalization
- Hormone secretion
- Health / Cancer? (melatonin hypothesis)

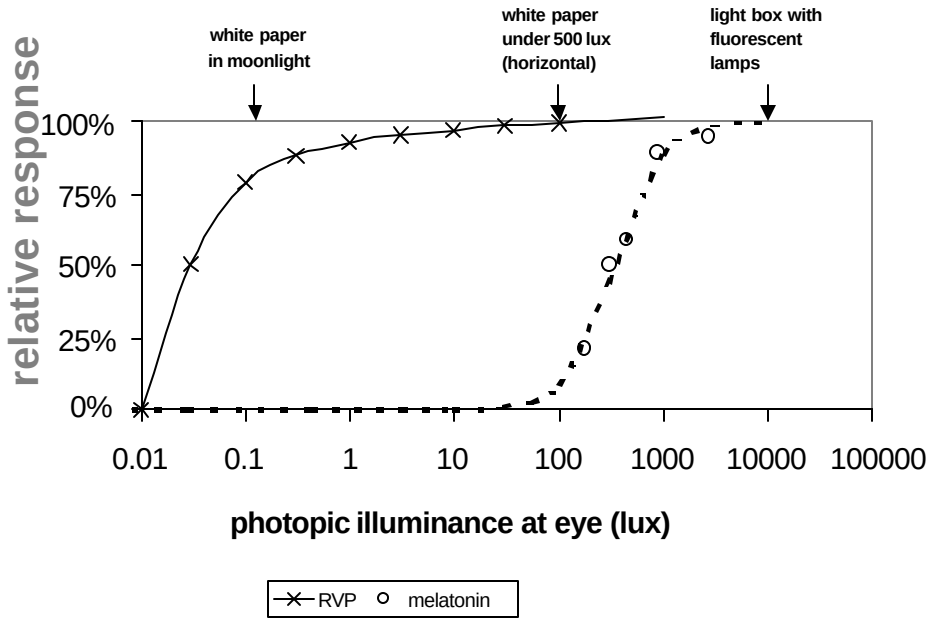
What factors determine effectiveness of light exposure?

To regulate circadian system:

- Retinal illuminance
- Spectrum
- Timing
- Duration of exposure
- Distribution

Retinal Illuminance

- Higher than that required for vision
- Conventional lighting is borderline for influencing the circadian system

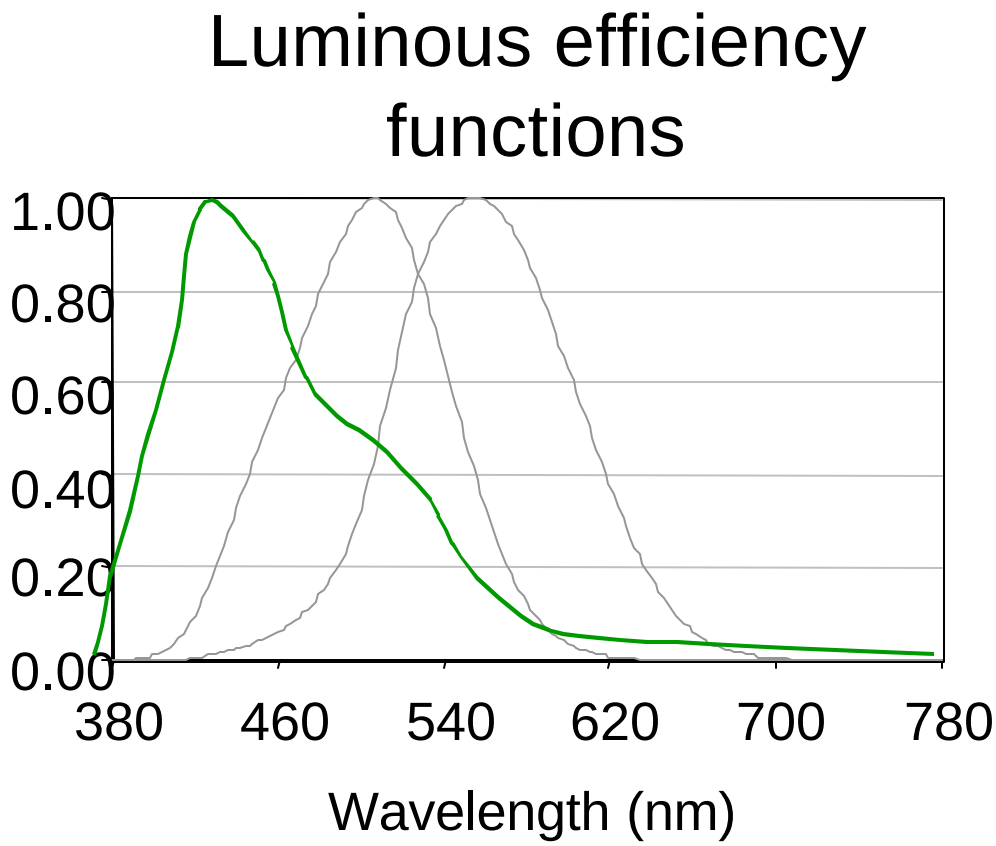


(McIntyre et al., 1989; Rea and Ouellette, 1991)

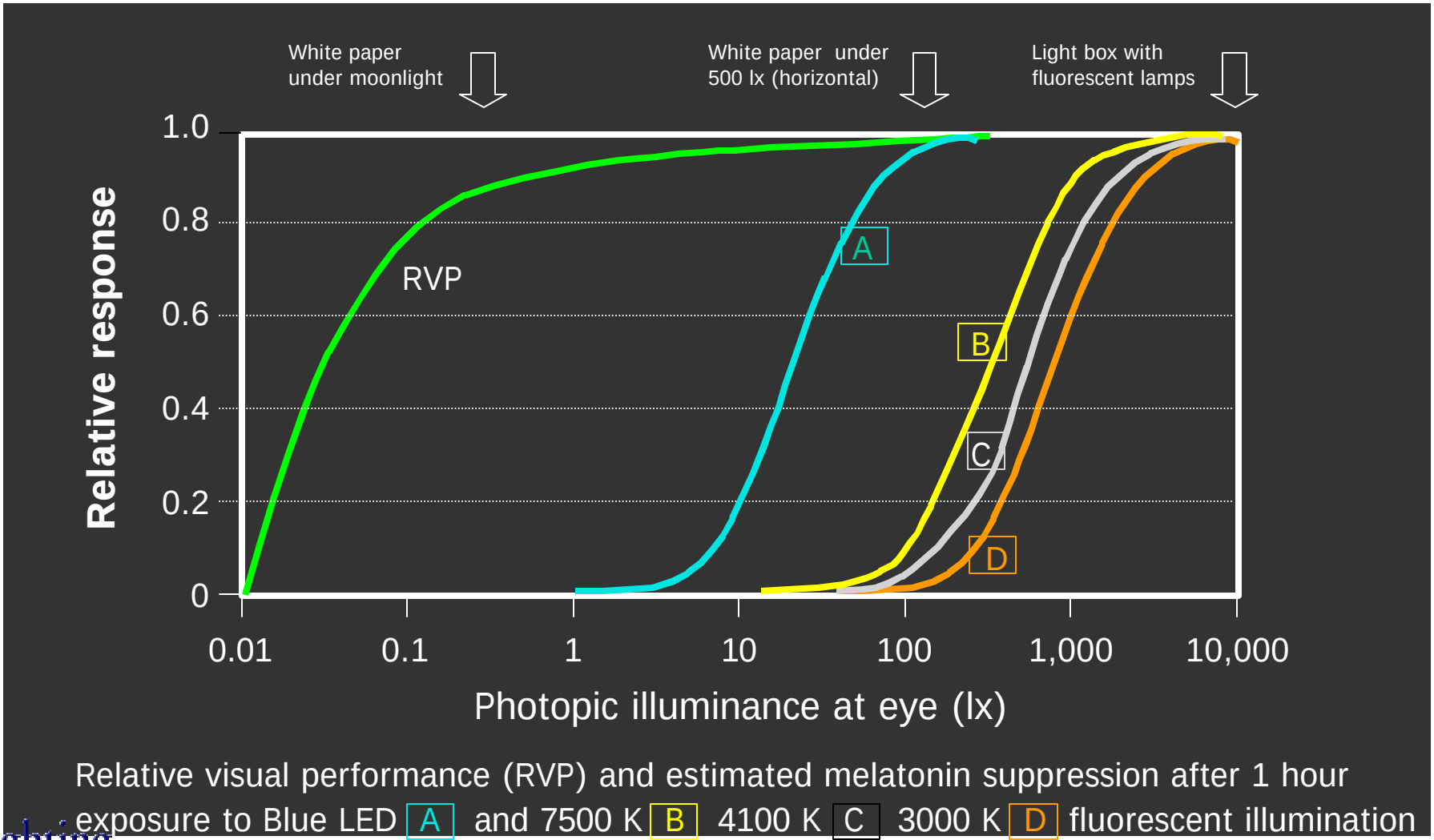
Spectrum

Spectral sensitivity peaks at around 460 nm

(Brainard et al., 2001; Thapan et al; 2001; Rea et al., 2002)



Spectrum



Relative visual performance (RVP) and estimated melatonin suppression after 1 hour exposure to Blue LED A and 7500 K B 4100 K C 3000 K D fluorescent illumination

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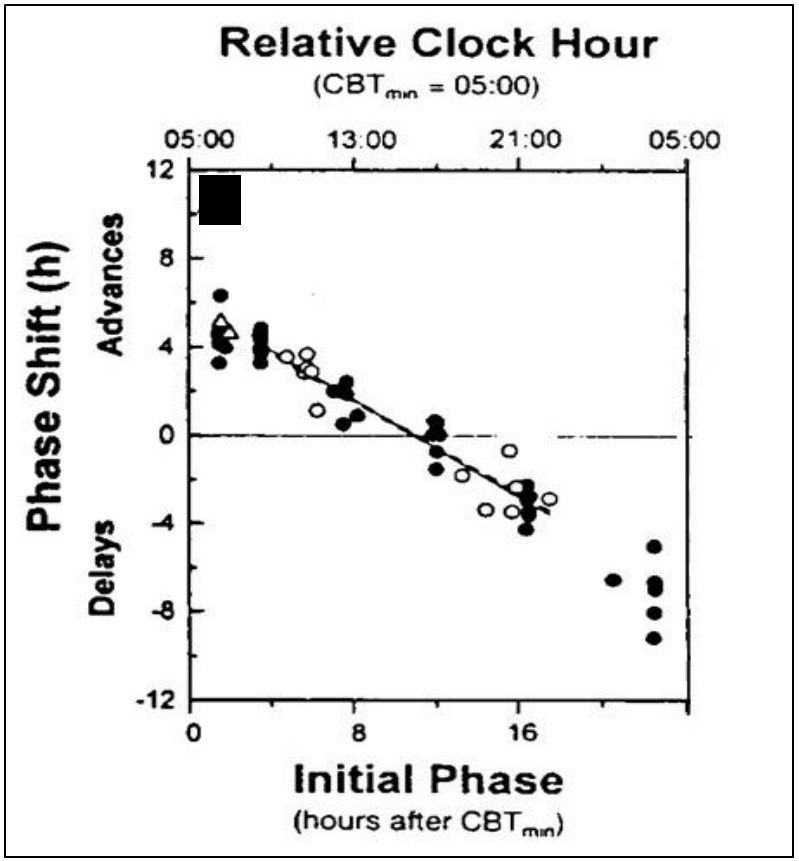
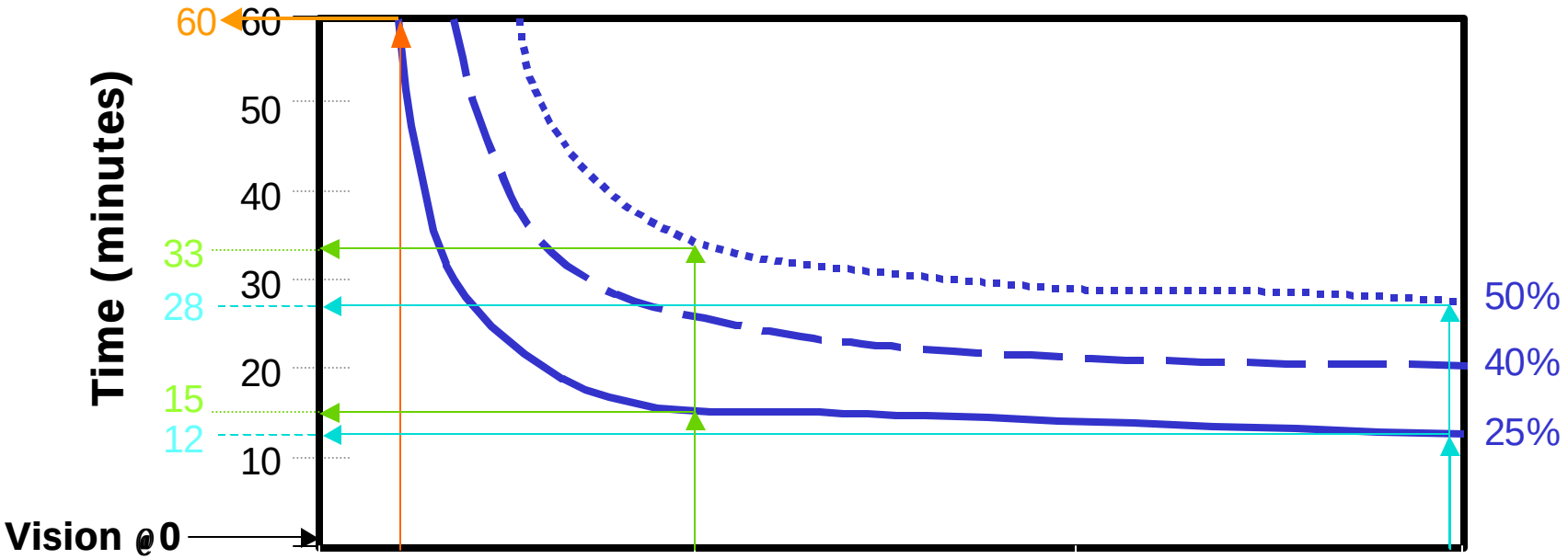
Timing

Bright light exposure can phase shift the circadian clock (Jewett et al., 1997)

- Evening light – "phase delay"
- Morning light – "phase advance"



Duration



Photopic illuminance at eye (lx)

The amount of time required to measure human nocturnal melatonin suppression by light, as a function of the illuminance provided at the eye (based on McIntyre et al, 1989).

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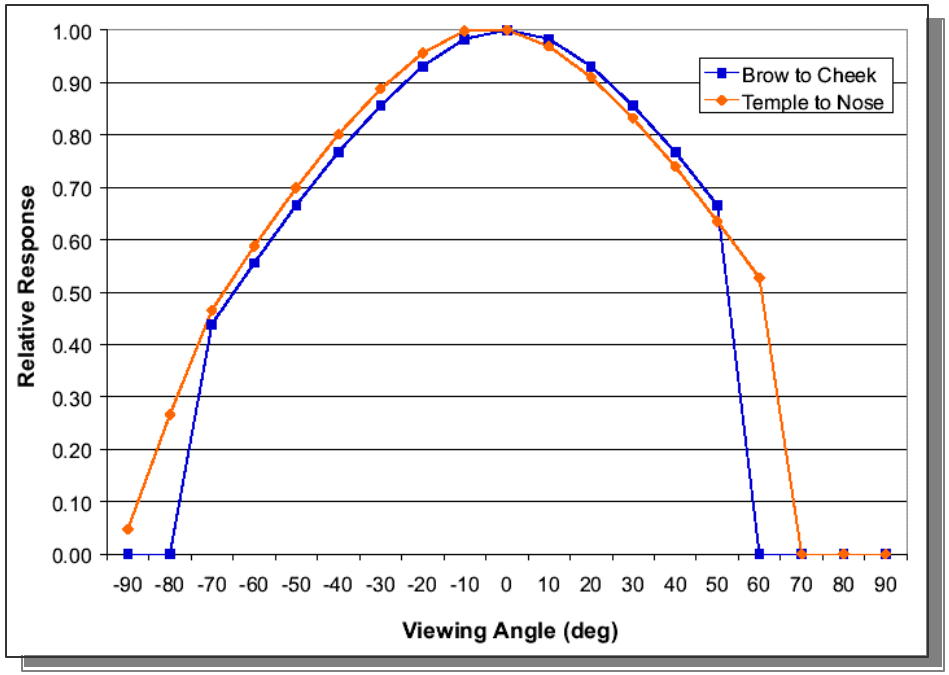
Distribution



What is the role of melatonin in the circadian system?

- "Hormone of darkness"
- Marker for circadian state
- Instructs the body to slow down/sleep
- Inversely proportional to body temperature (and wakefulness)
- Light suppresses production of melatonin

Recent LRC Work
Light and Circadian System

- Spectral sensitivity of circadian system
- Alzheimer's Disease
- Daylight and productivity
  - Field study
  - Lab study
- Upcoming circadian work
- Other "light" and health work (UV)

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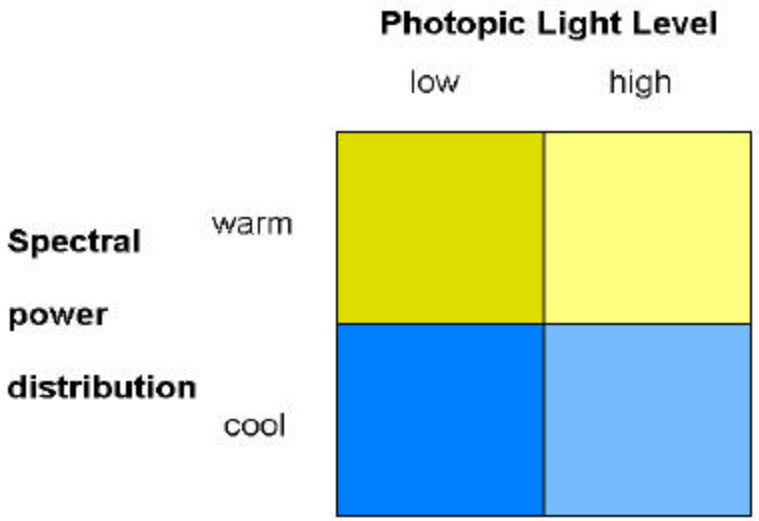
Circadian Spectral Sensitivity

What is the optimal light spectrum to maintain circadian photobiology?

Circadian Spectral Sensitivity

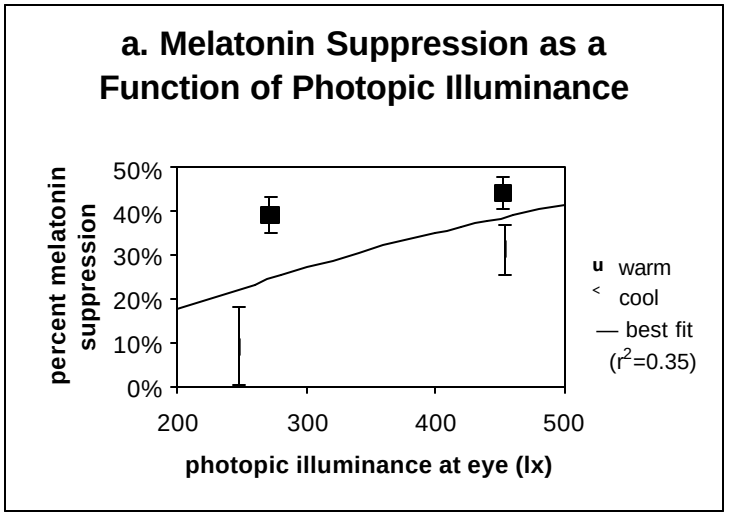


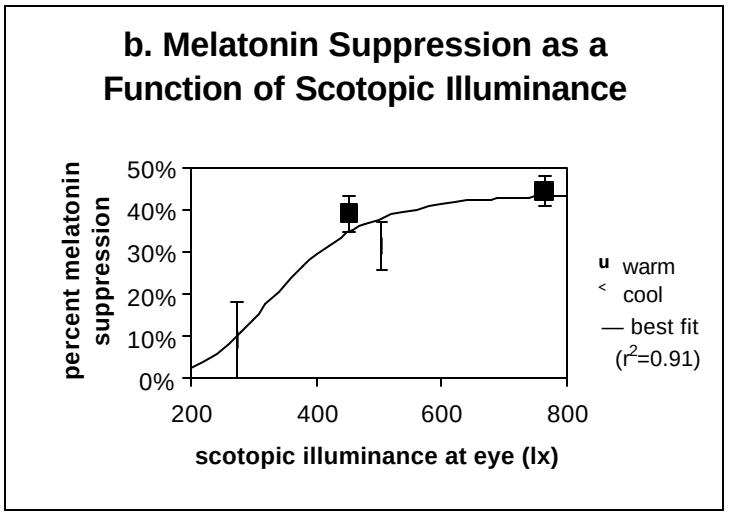
"warm" and "cool" spectra

"warm high" and "cool low" had the same scotopic illuminance at the eye

measured suppression of melatonin in bloodstream after 45 minutes

Spectral Sensitivity: Results





Results more consistent with rods (scotopic) than with cones (photopic) spectral sensitivity

- shorter-wavelength mechanisms could not be ruled out
- emerging data describing a peak near 460 nm
- could short-wavelength cones be involved?

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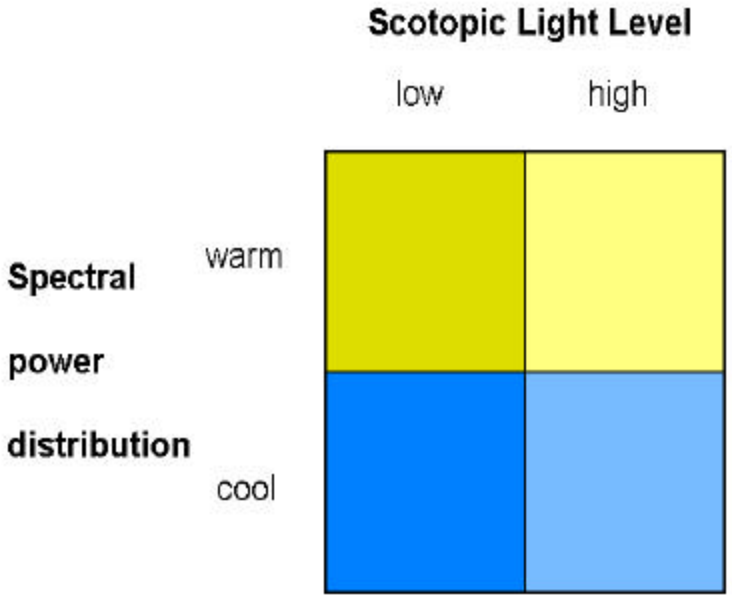
Circadian Spectral Sensitivity: Part Two

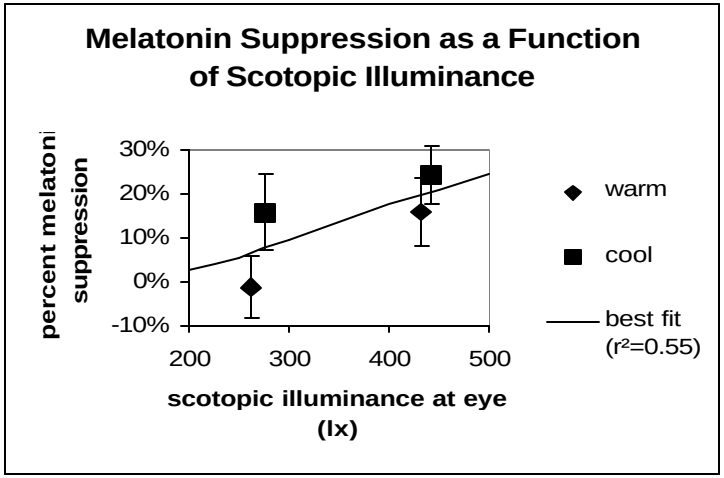


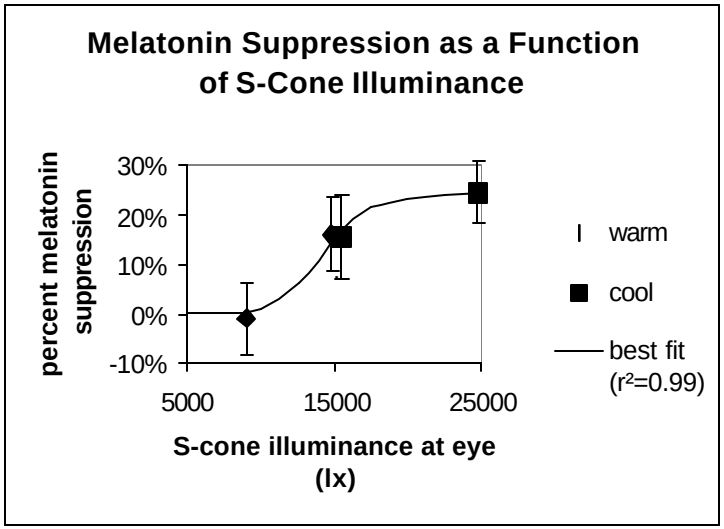
We used the same methodological approach, now contrasting rods (scotopic) and short-wavelength cones

“warm high" and "cool low" had the same "S cone" illuminance at the eye

Same experimental subjects, methods, procedures

Results: Round Two





These results seem to rule out rods as the dominant mechanism

Results are consistent with short-wavelength cones, a combination of short-wavelength cones and rods, or melanopsin, a previously unknown photopigment recently discovered in the retina

- or any combination having a peak sensitivity near 460 nm

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  - Field study
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Light and Alzheimer's Disease (AD)

- Irregular sleep cycles common in AD patients
- Institutionalized older adults are typically exposed to little bright light during the day

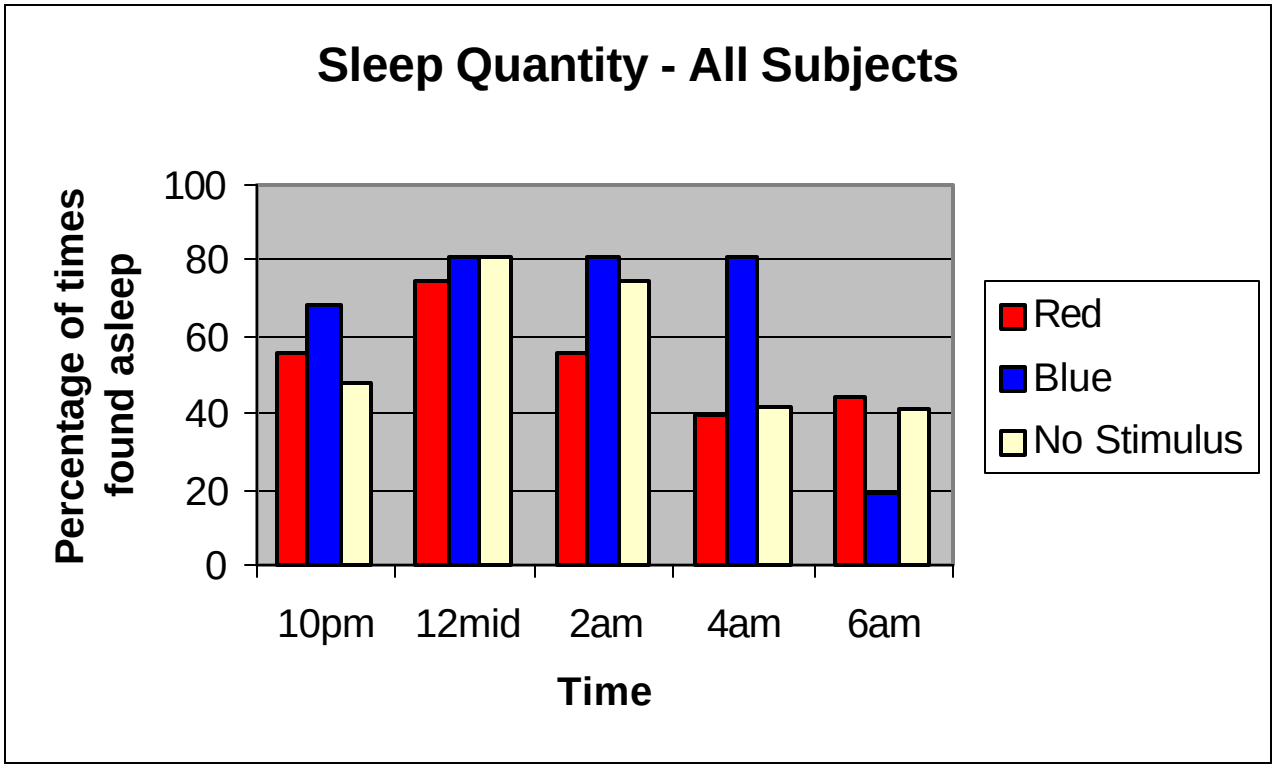
(Sanchez et al., 1993; Campbell et al., 1988)

AD Study

AD Study - Methods

- Lighting Conditions
  - Ambient light (300 lux on table) provided by fluorescent lamp fixtures
  - Red LEDs (630 nm)
  - Blue LEDs (470 nm)
- two-hour sessions (18:00 to 20:00 hours) for 10 days

AD Study - Results



Patients slept better between 02:00 and 04:00, after blue light exposure (compared to red)

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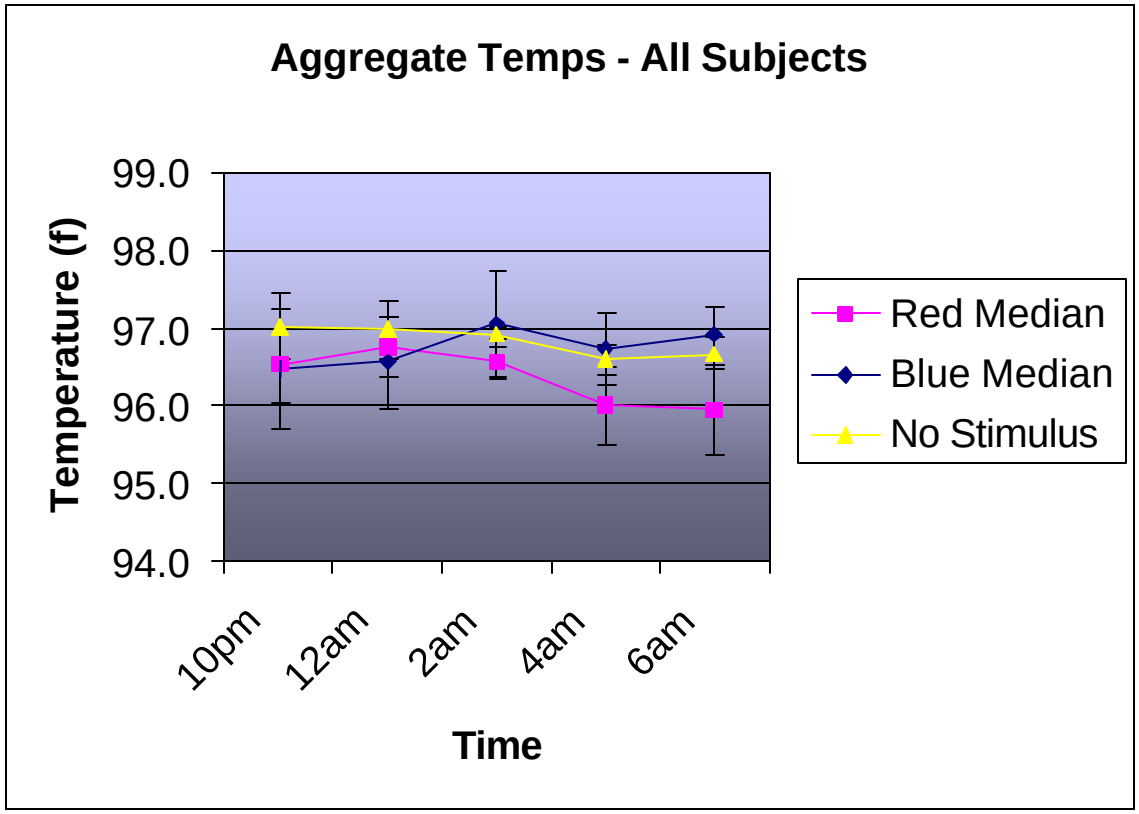
AD Study - Results



Blue light exposure delayed the decline of their body temperatures by 2-hours compared to red light exposure

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AD Study - Next Steps

- Replicate the study in a larger population for longer periods of time
- Work with manufacturers to develop portable light fixtures that can be used for this application

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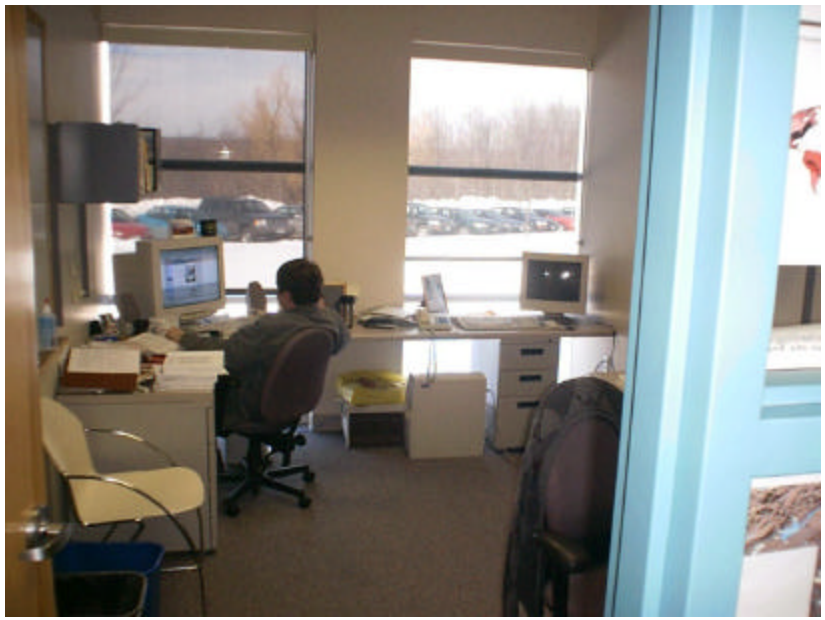
Daylight and Productivity - Field Study

Does circadian disruption affect productivity?



Typical windowed office

Typical interior office

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Field Study - Hypotheses

Based on the framework for circadian regulation we hypothesized that:

1) Workers in windowed offices would spend more time in their offices than workers in non-windowed offices

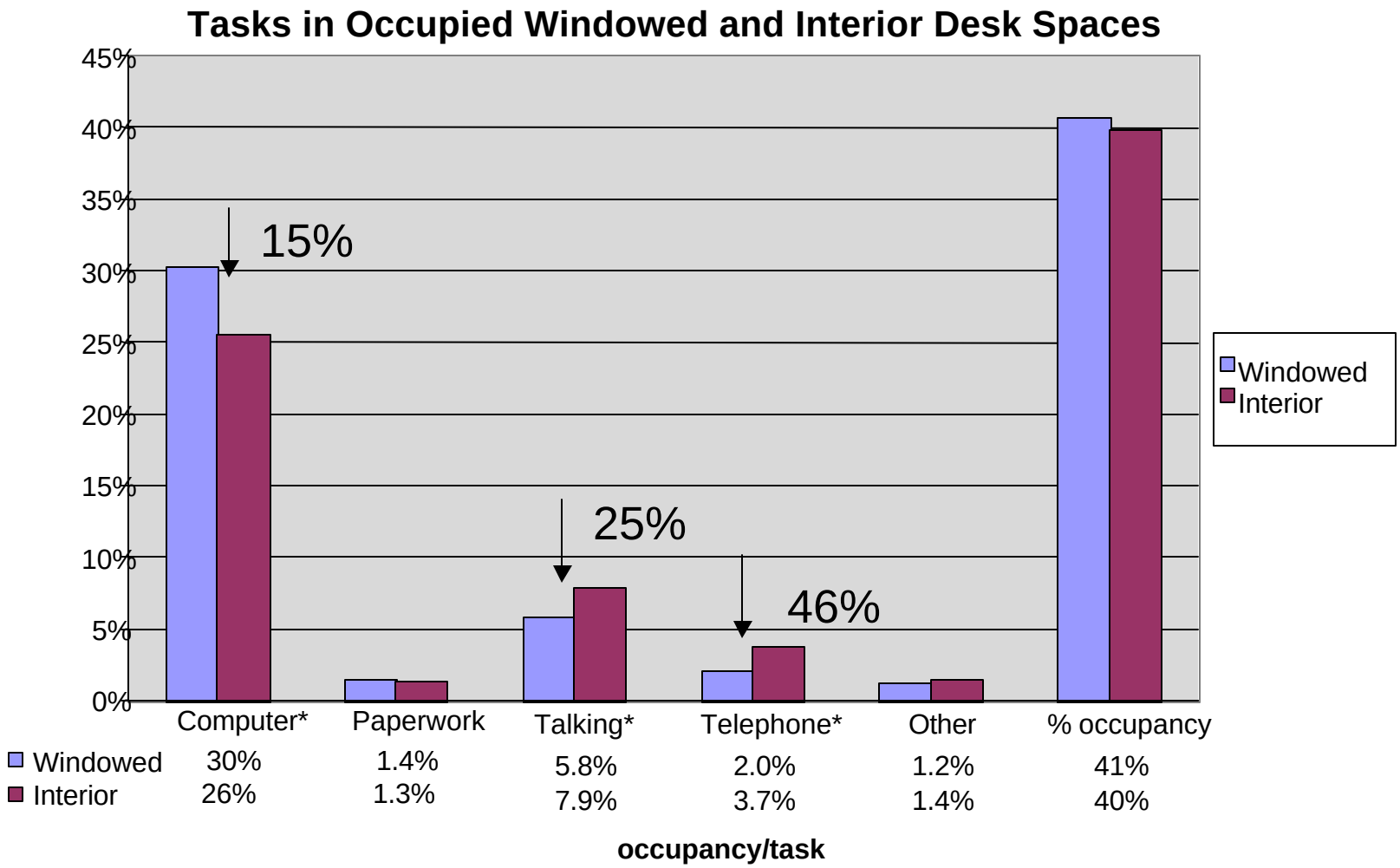
2) Workers in windowed offices would be working on the computer longer than workers in non-windowed offices

Daylight and Productivity - Field Study

Although occupancy rates for non-executive offices were the same, workers in windowed offices spent:

- Significantly more time on computer tasks (15%)
- Significantly less time talking to co-workers (25%)
- Significantly less time talking on the telephone (46%)

Field Study - Results



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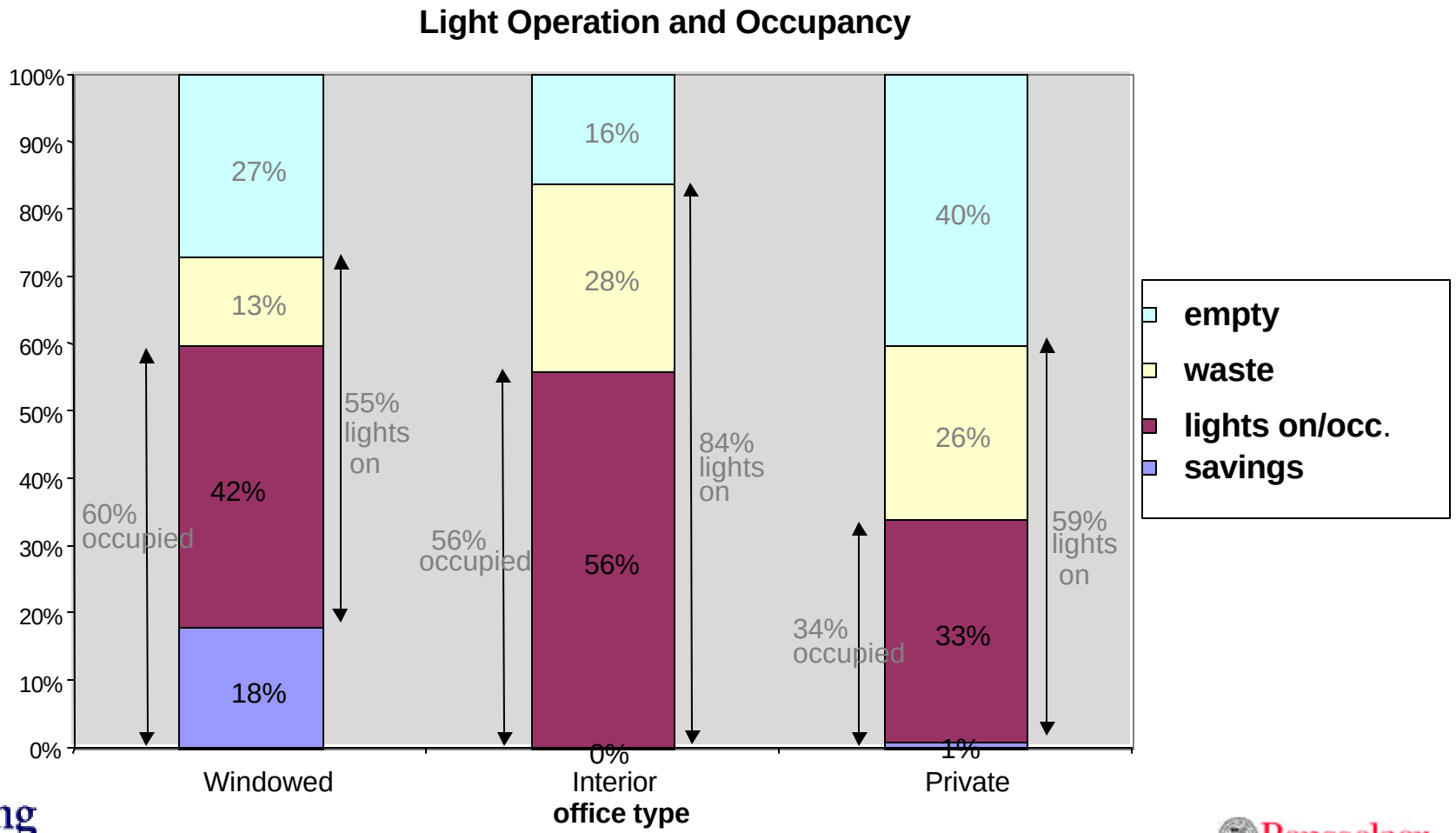
Field Study - Energy Results

- Lighting energy was “saved” 18% of the time in windowed offices compared to 1% in interior offices (occupied, lts off)
- Lighting energy was “wasted” 28% of the time in interior offices compared to 13% in windowed offices (unoccupied, lts on)
- Interior offices had more supplementary (inefficient) lighting than windowed offices, 63% vs. 37%

Daylight and Productivity – Field Study



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Lab Study – Experimental setup

- Held in Jan-Feb 2003
- Subjects arrived before sunrise, left after sunset
- Half exposed to daylight
- Others deprived of circadian cues
- After 4 days, weekend, then groups switched

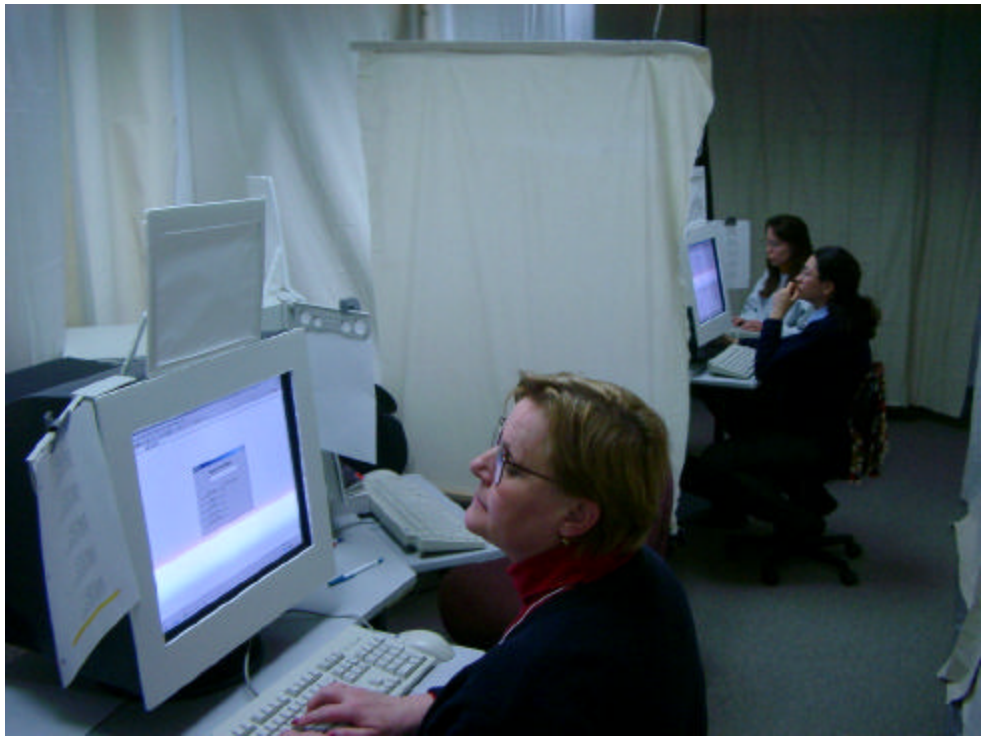
Lab Study – Experimental setup

- Performed office tasks for 8 hours

- Monitored
  - Breaks
  - Caffeine intake
  - Food intake

Lab Study – will analyze

- Productivity
- Compensatory behaviors
  - Occupancy / breaks
  - Caffeine
  - Food / Beverage



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Upcoming work

- Circadian spectral sensitivity
- Impact of light at night on melatonin
  - Day/night ratios
  - Light at night and breast cancer
- Severely phase-advanced teenagers
- Neonatal intensive care units

Recent LRC Work
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- **Other "light" and health work (UV)**

Light and Circadian System

- Blood Studies
- Alzheimer's patients
- Daylight and productivity
  - Field study
  - Lab study
- **Other "light" and health work (UV)**
- Upcoming work

Other “Light” and Health

- Ultraviolet germicidal irradiation
  - Tuberculosis transmission control
  - Bioterror threats
  - Lighting Answers-type publication
  - Due March 2003
- UV Water purification study (upcoming)


Controlling Tuberculosis Transmission with Ultraviolet Irradiation

Upper room ultraviolet germicidal irradiation at St. Agnes Shelter for the Homeless

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